

CLAIMS

What is claimed is:

1. A high pressure system, comprising a high pressure apparatus including:
 - a) a plurality of pressure members configured to form a high pressure volume; and
 - b) a first high pressure reaction assembly configured for placement in the high pressure volume, said reaction assembly comprising:
 - i) a first catalyst layer having a crystal growth surface and a raw material flux surface;
 - ii) at least one crystalline seed contacting the catalyst layer; and
 - iii) a raw material layer adjacent the raw material flux surface of the first catalyst layer, the raw material layer being configured to allow raw material to diffuse into the catalyst layer along a bulk raw material diffusion direction that is oriented substantially perpendicular to gravity during application of high pressure.
- 15 2. The system of claim 1, further comprising a second catalyst layer having a crystal growth surface and a raw material flux surface and at least one crystalline seed contacting the second catalyst layer, said raw material flux surface of the second catalyst layer being adjacent the raw material layer opposite the first catalyst layer.
- 20 3. The system of claim 1 or 2, further comprising a support layer in contact with the crystal growth surface of the catalyst layer.
4. The system of claim 3, wherein the crystalline seed contacts the crystal growth surface and the support layer at least partially surrounds each crystalline seed.
- 25 5. The system of claim 4, further comprising a second reaction assembly adjacent the first wherein the first and second reaction assemblies share a common support layer.
6. The system of claim 3, further comprising a plurality of reaction assemblies oriented in series within the high pressure volume.

7. The system of claim 1, further comprising a plurality of high pressure apparatuses oriented in parallel.
8. The system of claim 1, further comprising a plurality of high pressure apparatuses 5 oriented in series.
9. The method of claim 1, wherein the raw material is a carbon source configured for growing diamond from the crystalline seed.
- 10 10. The system of claim 9, wherein said catalyst layer comprises a carbon solvent selected from the group consisting of Fe, Ni, Co, Mn, Cr, and alloys thereof.
11. The system of claim 10, wherein said catalyst layer comprises an Fe-Ni alloy.
- 15 12. The system of claim 9, wherein said raw material layer comprises low resistivity graphite.
13. The system of claim 9, wherein said raw material layer comprises diamond powder.
- 20 14. The system of claim 1, wherein the raw material is a low pressure phase boron nitride source configured for growing cubic boron nitride from the crystalline seed.
15. The system of claim 14, wherein the catalyst material is a member selected from the group consisting of alkali, alkaline earth metal, and compounds thereof.
- 25 16. The system of claim 1, wherein the crystalline seed is a member selected from the group consisting of diamond seed, cBN seed, SiC seed, and combinations thereof.
17. The system of claim 1, wherein said plurality of pressure members comprises a high 30 pressure press selected from the group consisting of split die device, piston-cylinder press, girdle device, belt device, tetrahedral press, cubic press, and toroidal device.

18. The system of claim 17, wherein said pressure members are a split die device, comprising:

- 5 a) a plurality of complementary die segments, each die segment having an inner surface and an outer surface, wherein the inner surfaces are configured to form a die chamber having a chamber axis upon assembly of the plurality of die segments, said chamber axis being oriented substantially perpendicular to gravity during application of high pressure;
- 10 b) a pair of anvils oriented such that an anvil is at each end of the die chamber and configured to apply force substantially along the chamber axis; and
- 15 c) a plurality of force members operatively connected to the plurality of die segments and configured to apply a plurality of discrete forces to the plurality of die segments sufficient to retain the plurality of die segments in substantially fixed positions relative to each other during application of force by the pair of anvils.

19. The system of claim 18, comprising from two to ten complementary die segments.

20. The system of claim 18, wherein the die chamber has a length of from about 0.5 to about 10 times the minimum diameter.

21. The system of claim 18, wherein the discrete forces intersect at a common point and act in a common plane substantially perpendicular to the chamber axis.

22. The system of claim 18, wherein the die chamber has a reaction volume from about 5 cm³ to about 500 cm³.

23. The system of claim 18, further comprising a plurality of split die devices oriented in series, wherein said devices share at least one common anvil, said anvil having two ends, each configured to apply force substantially along the chamber axis.

24. The system of claim 18, further comprising a plurality of split die devices oriented in parallel, wherein said devices share common force members.

25. A method of growing crystalline bodies at high pressures, comprising:

5 a) providing a high pressure apparatus having a die chamber and a high pressure volume within the die chamber, said die chamber having a chamber axis;

10 b) assembling a high pressure reaction assembly having a plurality of crystalline growth cells aligned substantially along an assembly axis, each growth cell including a crystalline seed, a catalyst layer, and a raw material layer;

15 c) placing said high pressure reaction assembly at least partially within the high pressure volume such that the assembly axis is oriented substantially perpendicular to gravity; and

17 d) applying a pressing force to the reaction assembly substantially along the chamber axis which is sufficient to provide high pressures within the reaction assembly.

26. The method of claim 25, further comprising the step of orienting the high pressure apparatus prior to applying a pressing force, such that said chamber axis is substantially perpendicular to gravity.

20 27. The method of claim 25, wherein each crystalline growth cell comprises:

25 a) the catalyst layer having a crystal growth surface and a raw material flux surface;

27 b) the crystalline seed contacting the catalyst layer; and

29 c) the raw material layer adjacent the raw material flux surface, the raw material layer being configured to allow raw material to diffuse into the catalyst layer along a bulk raw material diffusion direction which corresponds generally to the assembly axis.

30 28. The method of claim 25, wherein the high pressure apparatus is selected from the group consisting of split die device, girdle device, belt device, piston-cylinder press, and toroidal device.

30 29. The method of claim 28, wherein the high pressure apparatus is a split die device.

30. The method of claim 29, wherein the pressing force is sufficient to provide ultrahigh pressures.

5 31. The method of claim 30, wherein the ultrahigh pressures are from about 4 GPa to about 7 GPa.

10 32. The method of claim 25, further comprising the step of actively controlling temperature profiles within the plurality of growth cells, such that each crystal growth surface has a lower temperature than a corresponding raw material flux surface.

15 33. The method of claim 32, wherein the step of actively controlling temperature profiles includes providing heating elements in thermal contact with the raw material layers and cooling elements in thermal contact with the crystal growth surfaces.

34. The method of claim 33, wherein the crystalline seeds are diamond seeds and during the step of applying a pressing force the diamond seeds grow to form gem quality diamonds.

20 35. The method of claim 34, wherein said gem quality diamonds have a size of from about 0.25 carat to about 25 carats.

36. The method of claim 25, wherein the crystalline seed is contacting the crystal growth surface and is substantially surrounded by a support layer.

25 37. The method of claim 36, wherein the support layer substantially comprises NaCl.

38. The method of claim 25, wherein the step of assembling further comprises assembling a plurality of high pressure reaction assemblies.

39. The method of claim 38, wherein the plurality of reaction assemblies is placed within the high pressure volume in a series relationship and wherein the assembly axes are each oriented substantially perpendicular to gravity.

5 40. The method of claim 38, further comprising a plurality of high pressure apparatuses oriented in parallel, wherein the plurality of reaction assemblies is placed in the high pressure volumes of the plurality of high pressure apparatuses.

10 41. The method of claim 38, further comprising a plurality of high pressure apparatuses oriented in series, wherein the plurality of reaction assemblies is placed in the high pressure volumes of the plurality of high pressure apparatuses.

42. A method of growing crystalline bodies at high pressures, comprising:

15 a) forming a reaction assembly including at least one crystalline seed, a catalyst layer, and a raw material layer, said reaction assembly being configured for temperature gradient controlled growth having a temperature gradient from the crystalline seed to the raw material;

20 b) orienting the reaction assembly such that the temperature gradient is substantially perpendicular to gravity; and

 c) applying high pressure and high temperature sufficient to cause diffusion of raw material along a bulk diffusion direction such that the raw material layer has a temperature higher than a temperature of the crystalline seed.